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Original Article

Influence of Ball Attachment Diameter and Inter-implant Distance on Retention of Mandibular Overdenture: An in Vitro Study

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Abstract

Objectives: To assess the effect of three different diameters of ball/ socket attachments and inter-implant distances (IIDs) on the retention of 2 implants as compared with single implant retained mandibular overdentures.
Materials and Methods: Four transparent acrylic resin casts simulating a completely edentulous mandible were fabricated. The forces (N) needed to dislodge single and 2 implant retained mandibular overdentures were estimated by a universal testing machine. Four main groups were computed,12 subgroups; a single implant was placed in mid-line area with 3.5mm, 4mm and 4.5mmdiameter ball and socket attachments respectively and 2 implants with IIDs 25mm in the canine, 32mm in 1st premolar and 40mm in 2nd premolar regions connected to 3.5mm, 4mm and 4.5mm diameter ball/socket attachments respectively.
Results: Statistically significant differences were found between single implant with ball attachment diameters(3.5mm,4mmand 4.5mm), single implant at (4.5mm) and 2 implants at (3.5 mm) diameters, 2 implants with ball attachment diameters(3.5mm, 4mm and 4.5 mm) at (25mm and 32mm and 40mm) IIDs and (25mm and 32mm and 40mm) IIDs at (3.5mm and 4 mm)ball attachment diameters, $P \leq 0.05$, but it was non-significant at 4.5mm ball attachment diameters, $P > 0.05$.The interactions between IIDs and the diameter of ball/ socket attachments were statistically non significant, $P> 0.05$.
Conclusion: Increasing both ball and socket attachment diameters and the inter-implant distances had positively influenced the retention of mandibular overdenture.

Keywords: Dental implant, mandibular overdenture, denture retention, ball attachments.

Introduction

Many health problems may lead to complex interaction of multifactorial signs ending by teeth loss. If this left untreated, it might develop to full edentulism. Edentulism occurrence is still excessive amongst the old population. That is why it is judged as the utmost public health obstacle (Choi *et al.*, 2018).

Early researches managed prosthetic options to benefit from the remaining roots and teeth that might retain and support different prostheses. Overdentures are recommended to conserve remaining oral tissues that would enhance retention and stability (Al-Ghafli *et al.*, 2009).

In edentulous patients' therapy, mandibular implants are usually chosen to hold fixed and removable prostheses. It was reported that restoration of the edentulous mandible with a traditional denture is not the first option anymore. The alternative prosthetic choice for edentulous mandible is an implant-supported overdenture (Thomason, 2002).

For successful implant-retained overdentures, working and non-working loads should be evenly shared across denture bearing parts and the implants. Exaggerated loads might lead to bone micro-damage and resorption might develop around the implants. Nevertheless, implants cannot be positioned at paragon locations because of bone morphology and anatomical landmarks integration. The inclination and position of implants and the distances between them might affect those circumstances. The lengths, diameters, and number of the implants, as well as the sort and retentive value of the attachment, must be taken into consideration during implant-retained overdenture planning. Numerous studies were performed to assess the paragon site and the number of implants and type of attachment for implant-retained overdenture. So far, there is no prevalent consensus through authors (Uludag and Polat, 2012; Celik and Uludag, 2014).

Attachment assembly is a specific kind of tenacious structure utilizing adaptable patrix and matrix correlative elements. Matrix corresponds to the reservoir part of the assembly, while patrix corresponds to part comprising an interference fit that captures the matrix. Overdenture attachment assemblies may fix the implants as bar attachments or depart them from splinting as stud-type. Bar types were useful in situations of non-parallel implants and were assigned to possess the least ratio of complications, yet the incipient price is high and laboratory procedures are intricate. Un-splinted systems incorporate telescopic crowns, ball-type attachments, magnets and locator attachments. In patients with lesser inter-arch distances, stud attachments are preferred and they are superior with regard to initial cost in addition to hygiene. For clinical implementation, the simplest kind of stud attachment is the ball attachment type. For two-implant mandibular overdentures, the ball attachment is most frequently used with profits like less price, simpler pattern, ample retention, and easier maintenance. Nevertheless, retentive nylon insert wear might lead to retention loss after six to nine months (Choi *et al.*, 2017; Salehi *et al.*, 2019).

Inter-implant distance (IID) could influence the wear ratio of retentive constituents, in addition to retention loss rate of attachments. Considerable wear will entail retentive constituents change during the maintenance period. Even though earlier researches have estimated different attachments' aspects, the possible consequences of various IIDs on attachment retention has infrequently been evaluated. IIDs were disregarded or arbitrarily chosen along those researches (Doukas *et al.*, 2006; Salehi *et al.*, 2019).

The current study has been handled for estimation of the effect of three different inter-implant distances and ball and socket attachment diameters on retention of 2 implant retained mandibular overdentures as compared with single implant retained mandibular overdentures.

The tested null hypothesis was that different IIDs and attachments' diameters would not have a significant impact on the retention.

Materials and Methods

This in vitro study was conducted using a standardized stone cast simulating a completely edentulous mandible without alveolar undercuts, so that retention was achieved with only the implant-connector assembly. The stone cast was duplicated to produce four transparent heat-cured acrylic resin casts (Acrostone, industrial area El Salam City, Egypt). Each cast represented a group according to implant position and was further divided into 3 sub-groups according to implant diameter in the following manner: three sub-groups were performed on the first cast:

1- **Single implant retained overdenture**

A. Group M-3.5: represented a single implant positioned in midline area with 3.5mm diameter ball and socket attachment.
B. Group M-4: a single implant positioned in midline area with 4mm diameter ball and socket attachment.
C. Group M-4.5: a single implant positioned in midline area with 4.5mm diameter ball and socket attachment.

On the second acrylic cast, another three subgroups were manipulated:

2- **Two implants retained overdenture**

A. Group C-3.5: 2 implants were positioned in the canine regions with3.5mm diameters ball and socket attachments.
B. Group C-4: 2implants were positioned in the canine regions with 4mm diameters ball and socket attachments.
C. Group C-4.5: 2implants were positioned in the canine regions with 4.5mm diameters ball and socket attachments.

On the third acrylic cast another three subgroups were performed:

A. Group 1P-3.5: 2 implants were positioned in the first premolar regions with 3.5mm diameters ball and socket attachments.
B. Group 1P-4: 2 implants were positioned in the first premolar with 4mm diameters ball and socket attachments.
C. Group 1P-4.5: 2 implants were positioned in the first premolar regions with 4.5mm diameters ball and socket attachments.

On the last acrylic cast, another three subgroups were performed:

A. Group 2P-3.5: 2 implants were positioned in the second premolar regions with3.5mm diameters ball and socket attachments.
B. Group 2P-4: 2 implants were positioned in the second premolar with 4mm diameters ball and socket attachments.
C. Group 2P-4.5:2 implants were positioned in the second premolar regions with 4.5mm diameters ball and socket attachments.

The mandibular complete denture was constructed from heat-cured acrylic resin (Acrostone, industrial area El Salam City, Egypt) on the stone cast in the usual manner. Three holes were drilled on the acrylic denture base at tripodal locations, two holes at the first molar regions and a hole between the two incisors; to facilitate engaging the denture base to the load cell.

1- Single implant retained overdenture

For the first acrylic cast group M3.5, a mark was made at the midline of the cast. Drilling was done in the midline of the cast in the conventional manner. A few drops of monomer and a small mix of self-cure acrylic resin were added before implant insertion (Acrostone, industrial area El Salam City, Egypt). The implant was pushed into the hole and the excess acrylic resin was removed (solid screw TUT implant 11 mm height and 3.4 mm diameter; (ECDI), Egypt). The ball abutment of the ball and socket attachments 3.5mm diameter (TUT implant abutment; (ECDI), Egypt) was placed onto the implant using the corresponding driver. Shallow hole was made at the basal surface of the denture where an attachment is to be placed. The socket was placed over its opposing ball abutment on the cast and pick-up of the attachment was done in the conventional manner, fig 1.

The dislodgement force required to lift the denture was measured for group M-3.5. Then the ball abutment of 3.5mm diameter was removed from the implant and replaced by 4 mm diameter ball abutment and pick-up of the attachment was repeated. The dislodgement force required to lift the denture was measured for group M-4. The same procedure was repeated for 4.5mm diameter ball abutment and dislodgement force required to lift the denture was measured for group M- 4.5.

2- Two implants retained overdenture

For group C, a mark was made at the midline of the cast. An inter-canine distance line of length 25mm was drawn perpendicular to the midline, and a mark was carried out on both sides of the midline at a distance of 12.5mm guided by positions of artificial canine teeth in the constructed mandibular complete denture. Two implant holes were drilled parallel to each other at those marks using a dental surveyor (Ney Surveyor; Dentsply Intl). Two implants were pushed into the holes then two ball and socket attachments 3.5, 4 and 4.5 mm diameters were placed respectively onto the implants in the same manner as in group M.

Dislodging forces required to lift the denture for group C-3.5, group C-4 and group C-4.5were measured respectively.

For groups, 1P and 2P, the same steps as for group C were followed except a mark was carried out on both sides of the midline at 32 mm inter- implant distance in group 1P, while in group 2Pa mark was carried out on both sides of the midline at 40 mm inter- implant distance guided by positions of artificial teeth in the constructed mandibular complete denture.

Fig 1: Group M3.5; socket placed in the denture and ball attachment placed in the cast.

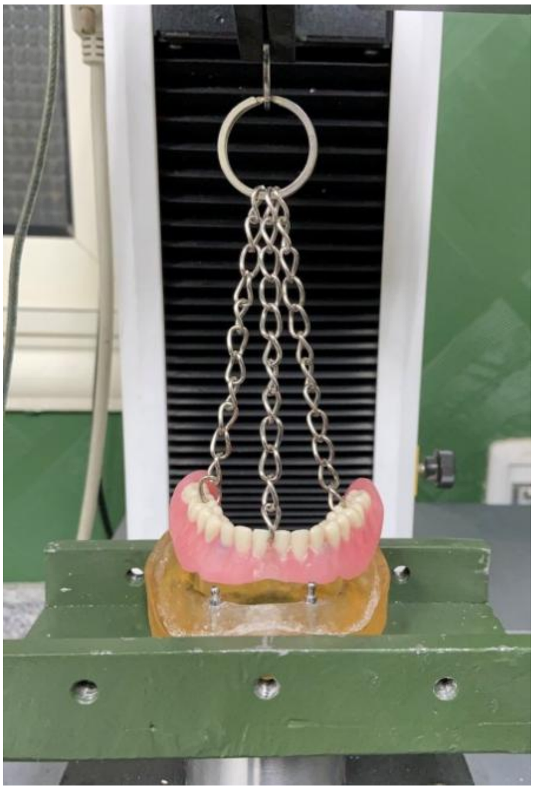

Fig 2: Suspension -Retention test for group C-4.5.

Casts of all groups were separately mounted on the lower fixed compartment of a computer-guided materials Advanced Universal testing machine (Model 3345, Instron, England) with 500N load cell. Three braided chains (10 cm long) connected the three holes of the overdenture to a custom made S-shaped steel hook, allowing self-adjustment of load line was secured to the upper movable compartment of advanced universal testing machine, fig 2.

The dislodgement force was measured for all groups in the following manner; overdentures were lifted upward at 5 mm/min crosshead speed. Values for these properties were carried out throughout the linear dislodgement slide, which was perpendicular to the occlusal plane. 10 pulls were applied for each overdenture of each group. The load required to lift up each overdenture as a function of vertical deflection was recorded with computer software (Bluehill Universal, Instron, England).

Statistical analysis

Statistical Package for Scientific Studies (SPSS 20) for Windows was used to analyze the computerized data. Shapiro-Wilk normality tests were carried out for constant variables and normally distributed data was disclosed. A mean and standard deviation were used to represent the quantitative data. The independent student's t-test was utilized to clarify the significance of differences between two variables, one-way ANOVA analysis and repeated measures ANOVA were performed to test the difference of the values between groups under study. The results were found to be significant at p-value ≤ 0.05.

Results

1- Effect of ball and socket attachment diameter on retention

A. Single implant retained overdenture

- Group M-3.5 showed the least dislodgement forces followed by group M-4 then group M-4.5; group M-3.5 < M-4 < M-4.5. A statistically significant difference was existed within groups, $p \leq 0.05$.
- Group M-4.5 showed the least dislodgement forces followed by group C-3.5 then group 1P-3.5 then group 2P-3.5; M-4.5 < C-3.5 < 1P-3.5 < 2P-3.5. A statistically significant difference was existed within groups, p=0.001.

B. Two implants retained overdenture

Group C-3.5, group 1P-3.5 and group 2P-3.5 showed the least dislodgement forces; group C-3.5 < C-4 < C-4.5, group 1P-3.5 < 1P-4 < 1P-4.5 and group 2P -3.5 < 2P -4 < 2P-4.5. Statistically significant differences were existed within groups, $p \leq 0.05$, table 1 and fig 3.

2- Effect of implant location and inter-implant distance on retention

- The dislodgement forces in group C-3.5 showed the least value followed by the group 1P-3.5 then group 2P-3.5; group C-3.5 < 1P-3.5< 2P-3.5. Statistically significant differences were found between groups, $p \leq 0.05$ except between groups 1P-3.5 and 2P-3.5, p=0.35.
- Also, the dislodgement forces in group C-4 showed the least value; group C-4<1P-4<2P-4. Statistically non-significant differences have existed between all groups, $p > 0.05$ except between groups C-4 and 1P-4, p=0.001.
- However, the dislodgement forces in group C-4.5 showed the least value; group C-4.5< 1P-4.5< 2P-4.5.Statistically non-significant differences have existed between all groups, $p > 0.05$, table 2 and fig 4.

3- Effect of inter-implant distance and diameter of ball and socket attachment on retention

A significant influence of the diameter ($p \leq 0.05$) on the dislodging force mean values, a significant influence of IIDs ($p \leq 0.05$) on the dislodging force mean values were showed. The interaction of these two factors was statistically non-significant, $p > 0.05$, table 3.

Table 1: Dislodgement forces (N) for each group at different diameters of ball attachments.

Inter-implant distance (IID) Implant (n = 7) Ball (n = 21)	Attachment diameters (Mean ±SD)			P -value
	3.5mm	4mm	4.5 mm	
Group M Implant (n = 1) Ball (n = 3)	3.58±0.17	4.16±0.02	5.31±0.01	0.0001*
Group C (25 mm) Implant (n = 2) Ball (n = 6)	13.81±0.01	15.51±1.14	16.63±0.74	0.001*
Group 1P (32 mm) Implant (n = 2) Ball (n = 6)	14.77±0.40	16.25±0.39	17.60±0.48	0.001*
Group 2P (40 mm) Implant (n = 2) Ball (n = 6)	15.39±0.49	16.79±0.83	18.12±0.57	0.007*

SD, Standard deviation.

*, Significant.

Table 2: Dislodgement forces (N) for each group at different inter-implant distances.

Attachment diameters	IIDs (Mean ±SD)			F	P-value
	Group C	Group 1P	Group 2 P		
3.5 mm	13.81±0.01	14.77±0.40	15.39±0.49	19.43	0.0001*
4 mm	15.51±1.14	16.25±0.39	16.79±0.83	3.05	0.05*
4.5 mm	16.63±0.74	17.60±0.48	18.12±0.57	1.23	0.28

SD, Standard deviation.

*, Significant.

Table 3: Repeated-measures ANOVA for dislodging force.

Effect	Sum of squares	Mean square	df	F	P-value
Diameter	117	1	58.6	197.9	0.0001*
IID	31.4	2	31.4	85.4	0.0001*
Diameter× IID	23.8	2	11.9	32.3	0.727

*, Significant.

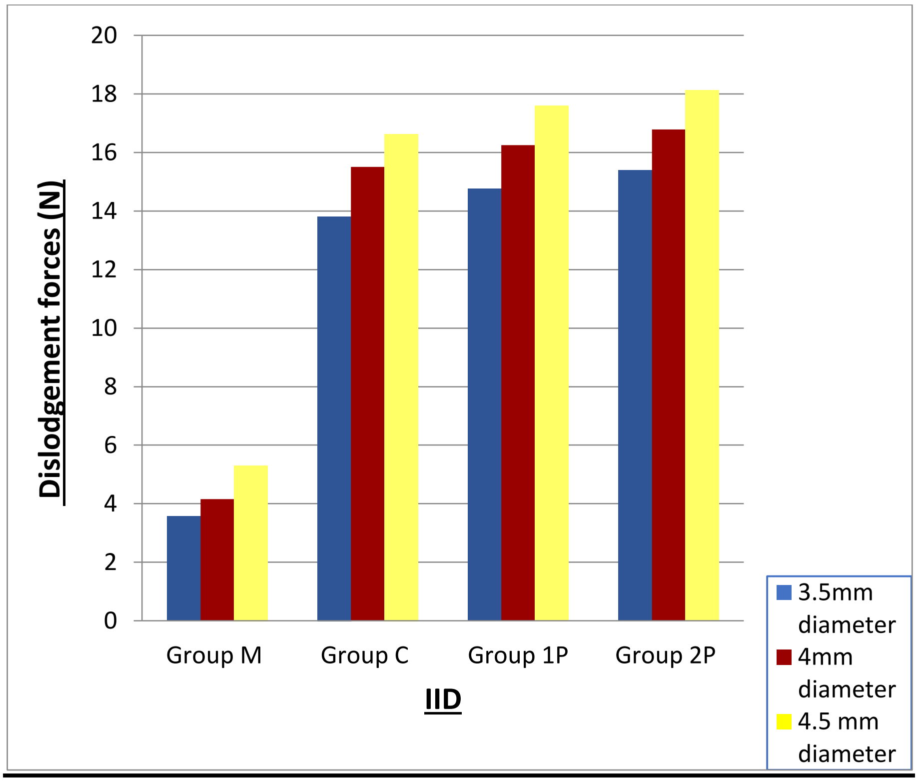

Fig 3: Dislodgement force (mean values) for groups at different attachments diameters .

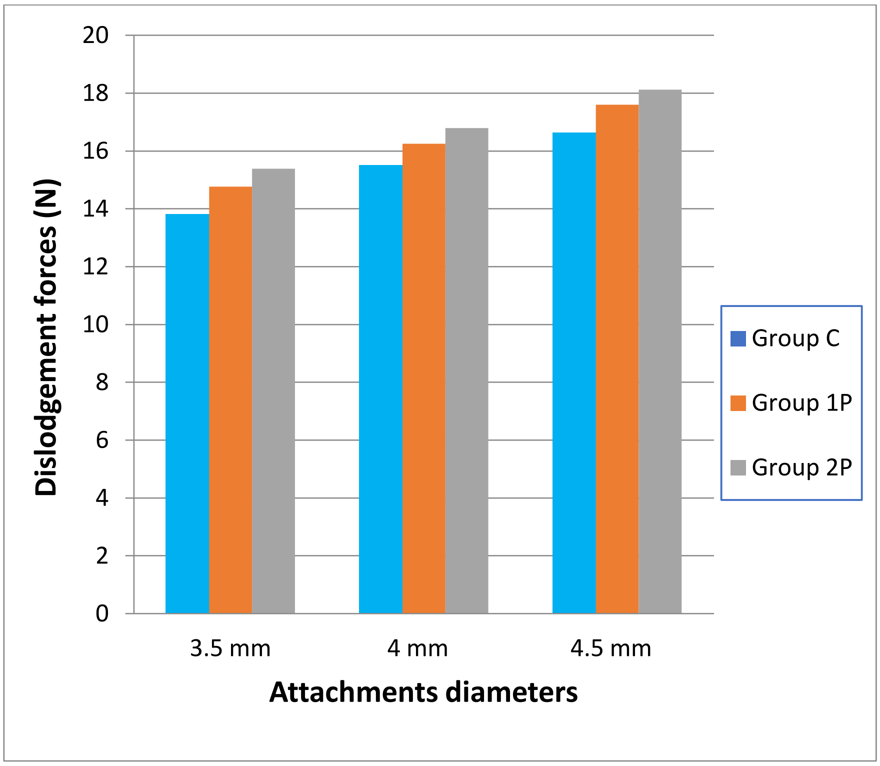

Fig 4: Dislodgement force (mean values) for groups at different IIDs .

Discussion

The current study was conducted using a standardized stone cast simulating a completely edentulous mandible without alveolar undercuts so that retention was achieved with only the implant-connector assembly. The stone cast was then duplicated to produce heat-cured acrylic resin casts. The mandibular complete dentures were then constructed from heat-cured acrylic resin. This is in simulation to the clinical situation as closely as possible since the way in which patients are instructed to remove their overdentures is to place their thumbs against the anterior flange of the prosthesis, at the site where implants are positioned, and lift the denture upwards by exerting concomitant force with both hands. Analogously, overdentures in the current research were lifted upward by way of the upper movable compartment of the universal testing machine, "since denture retention is defined as resistance to vertical force or resistance to displacement in a direction opposite to the path of insertion". Overdentures were lifted upward at crosshead speed of 5 mm/ min. Quantifications of these properties were accomplished throughout linear expulsion glide perpendicular to the occlusal plane. However, the clinical actuality of implant overdenture is more complicated than a laboratory assembly can simulate.

The current investigation has been conducted for estimation of the efficacy of various inter-implant distances and various ball and socket attachment diameters on retention of 2 implants as compared to a single implant retained lower overdenture. Rejection of the null hypothesis has been appraised, as results revealed that increasing the different IIDs and ball and socket attachment diameters had increased the retention. The least force level needed to displace the implants that were positioned at canine and midline sites, while the highest force was needed to displace implants positioned at second and first premolar sites due to resistance arm enhancement. This was in accordance with other previous studies (Scherer *et al.*, 2014; Taghi Baghani *et al.*, 2018).

The current investigation has been conducted in compliance with utilizing both single and two implant-retained mandibular overdentures to extend over majority of clinical favouritism of most practitioners. Stress distribution along the bone between single implant-retained and two implant-retained mandibular overdentures was compared in a study employing three-dimensional finite element analysis. It was ended that stress created in soft and hard bone was greater in single implant-retained mandibular overdenture. Meanwhile, the stress generated along the denture and implant was higher in two implant-retained mandibular overdenture (Lahoti, Pathrabe and Gade, 2016).

A correlation has been illustrated between ample retention and surpasses patient satisfaction. That is why choosing the attachment system of mandibular implant overdentures by most clinicians was established according to retentive capacity (Sadig, 2009; Rutkunas *et al.*, 2011; Geckili *et al.*, 2015). A six-month fatigue retention afforded by five paired mandibular overdenture attachments positioned at three different inter-implant spans was studied through in-vitro research. Calculation of mean fatigue retention was performed for each attachment type and was compared with retention generated by other tested attachments. Inter-implant span was launched to play a significant part only at the retention of one type of them. Nevertheless, a significant drop in retention values was recorded for four of five attachment types (Doukas *et al.*, 2006). However, this is not actually in agreement with findings of the present investigation as a significant influence of inter-implant distance on mean dislodging force values was reported due to increasing resistance arm. This ends up that findings of different researches have to be interpreted and compared tentatively according to used materials.

Even though retention and its impact upon overdenture prosthetic elements are interconnected, researches did not set up general agreement considering what is appraised as sufficient retention. Previous studies that assessed several kinds of attachments concluded that retention force in between five and eight Ns might be adequate for implant-retained overdentures throughout long term clinical service (Besimo and Guarneri, 2003; Jo *et al.*, 2014).

Lower single implant overdentures were reported as successful treatment choice for old edentulous adults intended for early loading procedure utilizing implants with various diameters and attachment systems (Alsabeeha *et al.*, 2011). Nevertheless, in the present investigation, increasing attachment diameters promoted retention in both single and 2 implant-retained assemblies, due to increasing frictional surface area.

Findings of the current in-vitro study also revealed that placing implants at second and first premolar locations might result in a more favourable position for implant-retained overdenture design in comparison with canine and incisor locations. This also could be attributed to the fact that the second and first premolar positions are more centrally located, allowing favourable force distribution rather than the farthest anteriorly located incisor and canine sites.

The interaction of the implant location and attachment diameter was non-significant. Nonetheless, those estimations did not inspect the clinical actuality of treating edentulous patients. However, additional researches should consider the biological fluid environment, fatigue efficacy on properties of materials, thermal cycling, and long term clinical studies to outright this research findings.

Conclusion

According to the followed methodology in this study; increasing both the inter-implant distances and ball and socket attachment diameters had positively influenced the retention of mandibular overdenture.

Conflict of interest

The authors declare no conflict of interest.

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None

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